Applications of TOMS Aerosol Data in Climate Forcing Studies

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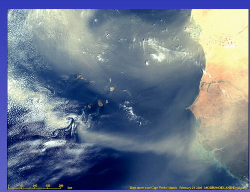
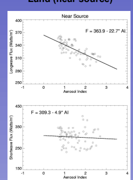
Saharan Dust

We first looked at forcing over Saharan dust. This RGB image was acquired by Terra/ MODIS as dust swept across the west coast of Africa to Cape Verde



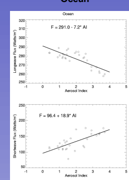
MODIS: February 29, 2000

Land (near source)

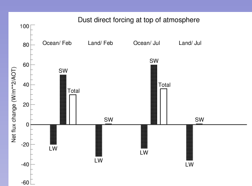


We determined the effect of such dust on both the longwave and shortwave forcing from ERBE over both land and ocean

Ocean



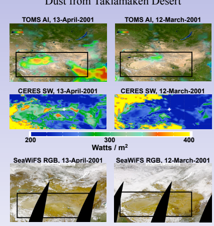
Our study indicated that Saharan dust generates a net cooling over the ocean and warming over land



Asian Dust

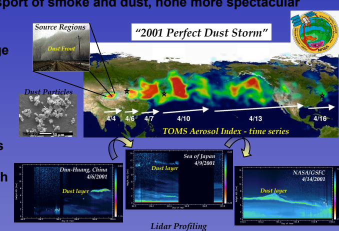
In another example, shown on the right, we compare TOMS aerosol index measurements, CERES shortwave measurements, and SeaWiFS RGB images for two different days over the Taklamaken desert. You can clearly see the change in forcing with and without dust

Dust from Taklamaken Desert

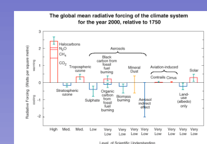


Introduction

For the last twenty five years, images of the Aerosol Index from the Total Ozone Mapping Spectrometer have provided us with dramatic examples of the long-range transport of smoke and dust, none more spectacular than the one depicting aerosol clouds from the huge April 2001 dust storms being transported across North America into the North Atlantic. Lidar measurements taken at different points along the path show the depth of this cloud along its journey.



The large uncertainty in understanding how aerosols affect forcing is indicated in the Intergovernmental Panel on Climate Change chart below. Reducing this uncertainty remains one of the major focus areas in climate studies.



How do we go about reducing the uncertainty of forcing due to aerosols?

Approach	Assumptions
Use a GCM / aerosol transport model	Must assume many of the aerosol properties
Use aerosol optical thickness derived (AOT) from satellite retrieval	Still must assume of the other aerosol properties
Use a combination of top-of-atmosphere flux determined from satellite with AOT determined from satellite	Don't need to assume aerosol properties

We chose the third approach by combining flux measurements from ERBE/CERES with aerosol measurements from SeaWiFS/MODIS and TOMS to compare radiation over dust and smoke to radiation over areas without dust and smoke.

How do you define climate forcing due to aerosols?

$$\text{Radiative forcing} = \underbrace{F^{\uparrow TOA} - F^{\uparrow TOA}_{clear\ sky}}_{\text{Longwave or Shortwave Flux}}$$

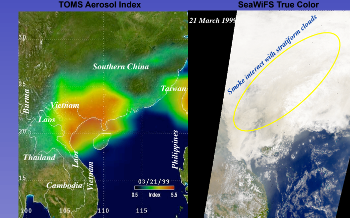
If we assume a linear relationship between TOA flux and aerosol loading

$$F^{\uparrow TOA} = F^{\uparrow TOA}_{clear\ sky} + \text{sensitivity} \times \text{Aerosol Index}$$

Asian Smoke

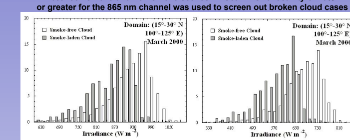
We are currently investigating what effect smoke has on forcing from clouds. We have concentrated on Southeast Asia. Every spring there are intensive biomass burning activities in this area, making it a natural one to study such complex interaction between smoke and cloud.

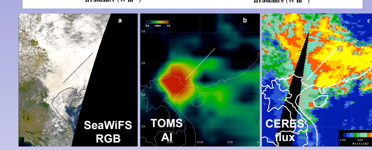
TOMS Aerosol Index SeaWiFS True Color



The histograms to the right show the effect that smoke has on the shortwave (left) and shortwave+longwave (right) upwelling flux from clouds over the region shown in the images below right for the month of March, 2000. You can clearly see that the reduction in outgoing shortwave flux when smoke aerosols occur in cloudy regions is substantial, leading to a strong warming in the smoke layer above the cloud deck.

A TOMS aerosol index value of 1.5 or greater was used to discriminate between smoke and non-smoke scenes. A SeaWiFS reflectivity of 70% or greater for the 865 nm channel was used to screen out broken cloud cases





Summary

By combining TOMS aerosol index with TOA flux information from earlier ERBE and recent CERES sensors, we have determined quantitatively the radiative forcing of Saharan dust and Asian dust over both land and ocean under cloud-free conditions.

We have also studied the radiative forcing of smoke aerosols in the cloudy regions of Southeast Asia, where there are intensive biomass burning activities during the springtime. The TOMS aerosol index provides an excellent measure of the presence of absorbing aerosol over clouds. By combining AI information with CERES flux products, as well as cloud information from SeaWiFS or MODIS, the change in the reflected solar radiation due to the presence of smoke aerosols over clouds was quantified in our studies.

Twenty-five years of the TOMS aerosol index product, when merged with radiation measurements from ERBE and CERES, provides a unique dataset to study the long-term change in the Earth's radiation budget due to both natural and man-made variation in aerosol loading.